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**Appendix 1**

**Sensitivity analysis ‒ Alternative operationalisations of happiness**

***Method***

In our primary analysis, we defined the happiness variable using all the three “positive” items (‘I felt happy’, ‘I enjoyed life’ and ‘I felt hope about the future’) from the CES-D [1]. While the items ‘I felt happy’ and ‘I enjoyed life’ are suggestive of hedonic happiness [5], the item ‘I felt hope about the future’ represents hope [4]. Hope is a distinct yet related construct ‒ it has been shown to be positively related to happiness [6, 7]. Thus, in **sensitivity analysis**, we operationalized happiness in the following ways:

1. Continuous **‘hedonic happiness score’** (sum of scores on ‘I felt happy’ and ‘I enjoyed life’; range: 0 to 4; higher value indicates a greater extent of hedonic happiness)
2. Continuous **‘hope score’** (scores on ‘I felt hope about the future’; range: 0 to 2; higher value indicates a greater extent of hope).

Furthermore, to assess if the association of the ‘binary happiness variable’ with all-cause mortality is sensitive to the choice of the cut-off (=6) used to dichotomize the happiness score, we also operationalized the ‘binary happiness variable’ using an alternate cut-off, i.e. ≥ 5. Thus, in sensitivity analysis, we also operationalized happiness as

1. **Binary happiness variable** (happy [happiness score ≥ 5] / unhappy [happiness score ≤ 4])

***Results***

The results of all the three sensitivity analyses (Supplementary Table 2) were similar to those observed in the primary analysis, i.e.

1. A unit increase in the ‘hedonic happiness score’ was associated with a 9% reduction in the likelihood of all-cause mortality.
2. A unit increase in the ‘hope score’ was associated with a 17% reduction in the likelihood of all-cause mortality.
3. Happy older people, compared to those unhappy, had a 23% reduced likelihood of all-cause mortality.

**Supplementary Table 1: Association of alternative operationalisations of happiness with all-cause mortality, multivariable Cox regression analysis**

|  |  |
| --- | --- |
| **Alternative operationalisations of happiness** | **Multivariable hazard ratio (95% CI) a** |
| 1. For each unit increase in the **‘hedonic happiness score’** | 0.91 (0.85-0.97)\*\* |
| 1. For each unit increase in the **‘hope score’** | 0.83 (0.76-0.91)\*\*\* |
| 1. **Binary happiness variable**, dichotomized at happiness score ≥ 5 (happy) versus happiness score ≤ 4 (unhappy) | 0.77 (0.66-0.90)\*\* |

CI: Confidence Interval

\*p<0.05, \*\*p<0.01, \*\*\*p<0.001

a Adjusted for demographic (age, sex, ethnicity, marital status, housing type, educational status, and living arrangement), lifestyle (physical activity, smoking status, alcohol intake, and sleep duration), health (body mass index category, self-rated health, number of chronic diseases, number of activity of daily living limitations, number of instrumental activity of daily living limitations, number of mobility limitations, depressive symptoms, and cognitive impairment status), and social (loneliness and social networks) variables.

**Appendix 2**

**Details on confounders**

**Demographic variables** included age, sex, ethnicity, marital status, housing type, educational status, and living arrangement. **Lifestyle variables** were **physical activity** (based on response to: How often [‘every day/every week/every month/less than once a month/not at all’] do you go for a walk for exercise purposes?; Yes [every day or every week]/No); **smoking status** (self-reported; non-smoker/past smoker/current smoker); **alcohol intake** (self-reported; none/occasional/current); and **sleep duration** (self-reported, in hours; ≤ 4/5/6/7-8/≥ 9 [8]).

**Health variables** included **body mass index** (weight in kilograms/square of height in meters [kg/m2], based on measured weight and height; categorized as per Asian classification into underweight/normal/overweight or obese [9]); **self-rated health** (very healthy/healthier than average/somewhat unhealthy/very unhealthy); **number of chronic diseases** (based on self-report of ever-diagnosed by medical professional with heart attack, angina, other form of heart disease, cancer, cerebrovascular disease, high blood pressure, and diabetes); **number of activity of daily living (ADL) limitations** (self-reported limitation in six activities: bathing or showering, dressing up, eating, standing up and sitting down on bed or chair, walking around the house, and toileting), **number of instrumental ADL** limitations (self-reported limitation in seven activities: preparing own meals, leaving the house for shopping, taking care of financial matters, using the phone, dusting or cleaning and other light housework, taking public transport and taking medication as prescribed); **number of mobility limitations** (self-reported on the nine-item Nagi’s index of physical performance [10]); **depressive symptoms** (participants were asked how often in the past week [Never or Rarely: 0; Sometimes: 1; Often: 2] they experienced the following nine negatively worded items on a 12-item CES-D scale [1]: ‘My appetite is poor’, ‘I felt depressed’, ‘My sleep was restless’, ‘I felt lonely’, ‘I felt people were unfriendly’, ‘I felt sad’, ‘I felt that people dislike me’, and ‘I could not get going’; total score [sum of item scores] range: 0-18; higher scores indicate greater extent of depressive symptoms); and **cognitive impairment** status (Short Portable Mental Status Questionnaire [11]; cognitively intact [score: 0-2]/mild impairment [score: 3-4]/moderate impairment [score: 5-7]).

Finally, **social variables** included **loneliness** (UCLA three-item loneliness scale [12]; range: 0-12; higher score indicating greater extent of loneliness); and **social networks** (12-item Lubben’s revised social network scale [13]; range: 0-30; higher score indicating better social networks).

**Appendix 3**

**Supplementary Table 2: Distribution of baseline demographic, health, lifestyle and social characteristics of older people in the analytical sample, by ‘binary happiness variable’ (Happy/Unhappy) and by all-cause mortality until 31 December 2015 (Alive/Dead)**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Binary happiness variable** | |  | **All-cause mortality until 31 December 2015** | |  |  |
|  | **Happy (n=1486a)** | **Unhappy (n=2992a)** |  | **Alive**  **(n=3665a)** | **Dead**  **(n=813a)** |  |  |
|  | **Mean ± SDb or N (Column %b)** | | **p-value** | **Mean± SDb or N (Column %b)** | |  | **p-value** |
| Age, years | 69.6 ± 7.3 | 68.4 ± 6.9 | <0.0001 | 68.4 ± 6.8 | 74.2 ± 7.5 |  | <0.0001 |
| Sex |  |  |  |  |  |  |  |
| Female | 670 (48.8) | 1731 (55.7) | <0.0001 | 2040 (55.0) | 361 (43.7) |  | <0.0001 |
| Male | 816 (51.3) | 1261 (44.3) | 1625 (45.0) | 452 (56.3) |  |
| Ethnicity |  |  |  |  |  |  |  |
| Chinese | 969 (79.4) | 2257 (85.4) | <0.0001 | 2666 (83.9) | 560 (80.4) |  | 0.08 |
| Malay | 338 (12.6) | 398 (7.4) | 569 (8.7) | 167 (11.8) |  |
| Indian | 150 (5.8) | 314 (6.3) | 387 (6.1) | 77 (6.5) |  |
| Others | 29 (2.2) | 23 (0.9) | 43 (1.3) | 9 (1.4) |  |
| Housing |  |  |  |  |  |  |  |
| 1-2 room HDB | 113 (6.1) | 279 (7.9) | <0.0001 | 300 (6.7) | 92 (10.9) |  | 0.0001 |
| 3 room HDB | 314 (20.2) | 890 (29.5) | 977 (26.2) | 227 (27.9) |  |
| 4-5 room HDB/Private | 1059 (73.7) | 1823 (62.6) | 2388 (67.1) | 494 (61.2) |  |
| Marital status |  |  |  |  |  |  |  |
| Married | 1039 (72.9) | 1654 (61.2) | <0.0001 | 2270 (66.7) | 423 (55.5) |  | <0.0001 |
| Widowed | 358 (19.6) | 1107 (29.8) | 1117 (24.6) | 348 (37.5) |  |
| Separated | 6 (0.5) | 23 (0.8) | 25 (0.7) | 4 (0.6) |  |
| Divorced | 21 (1.7) | 73 (2.9) | 82 (2.6) | 12 (2.0) |  |
| Never married | 62 (5.3) | 135(5.3) | 171 (5.4) | 26 (4.4) |  |
| Living arrangement |  |  |  |  |  |  |  |
| Living alone | 64 (4.2) | 222 (7.7) | <0.0001 | 238 (6.5) | 48 (6.7) |  | <0.0001 |
| With spouse, no children | 347 (24.3) | 490 (17.0) | 699 (19.6) | 138 (18.5) |  |
| With children, no spouse | 329 (18.3) | 1000 (27.0) | 1017 (22.6) | 312 (33.3) |  |
| With spouse and children | 660 (47.0) | 1118 (43.0) | 1504 (45.8) | 274 (35.6) |  |
| With others only | 86 (6.2) | 162 (5.3) | 207 (5.6) | 41 (5.9) |  |
| Education |  |  |  |  |  |  |  |
| No formal education | 377 (23.0) | 1146 (31.6) | <0.0001 | 1177 (27.0) | 346 (39.5) |  | <0.0001 |
| Primary school | 548 (33.8) | 1107 (38.9) | 1345 (37.1) | 310 (37.8) |  |
| Secondary school | 382 (28.5) | 575 (22.9) | 845 (26.3) | 112 (15.5) |  |
| Above secondary school | 179 (14.7) | 164 (6.6) | 298 (9.7) | 45 (7.2) |  |
| BMI category, kg/m2 | (n=1391) | (n=2755) |  | (n=3428) | (n=718) |  |  |
| <18.5 / Underweight | 87 (5.95) | 189 (6.5) | 0.14 | 196 (5.6) | 80 (10.7) |  | <0.0001 |
| 18.5-22.9 / Normal weight | 420 (31.1) | 896 (33.8) | 1068 (32.5) | 248 (35.3) |  |
| ≥23 / Overweight or Obese | 884 (62.9) | 1670 (59.8) | 2164 (61.9) | 390 (54.1) |  |
| Number of chronic diseases | 1.3 ± 1.2 | 1.5 ± 1.3 | <0.0001 | 1.4 ± 1.3 | 1.9 ± 1.2 |  | <0.0001 |
| Self-rated health |  |  |  |  |  |  |  |
| Very healthy | 190 (14.1) | 226 (8.3) | <0.0001 | 371 (10.9) | 45 (6.1) |  | <0.0001 |
| Healthier than average | 466 (34.3) | 873 (30.8) | 1180 (33.8) | 159 (20.6) |  |
| Of average health | 716 (44.6) | 1430 (46.6) | 1731 (45.4) | 415 (49.2) |  |
| Somewhat unhealthy | 109 (6.7) | 412 (12.6) | 347 (8.9) | 174 (21.1) |  |
| Very unhealthy | 5 (0.3) | 50 (1.7) | 35 (0.9) | 20 (3.0) |  |
| Not sure | 0 (0.0) | 1 (0.04) |  | 1 (0.03) | 0 (0.0) |  |
| CES-D Scale Score (9 negatively worded items) | 1.3 ± 1.7 | 2.8 ± 2.7 | <0.0001 | 2.2 ± 2.5 | 2.9 ± 2.6 |  | <0.0001 |
| Number of ADL limitations | 0.04 ± 0.3 | 0.1 ± 0.6 | <0.0001 | 0.05 ± 0.4 | 0.3 ± 0.8 |  | <0.0001 |
| Number IADL limitations | 0.1 ± 0.6 | 0.3 ± 1.0 | <0.0001 | 0.1 ± 0.7 | 0.7 ± 1.5 |  | <0.0001 |
| Number of mobility limitations | 0.5 ± 1.2 | 0.8 ± 1.6 | <0.0001 | 0.6 ± 1.3 | 1.5 ± 1.8 |  | <0.0001 |
| SPMSQ score | 1.6 ± 1.1 | 1.7 ± 1.4 | <0.0001 | 1.7 ± 1.3 | 2.0 ± 1.5 |  | <0.0001 |
| Smoking status |  |  |  |  |  |  |  |
| None | 1032 (72.3) | 2232 (74.3) | 0.01 | 2774 (76.2) | 490 (58.1) |  | <0.0001 |
| Past | 279 (16.5) | 424 (13.3) | 514 (13.0) | 189 (22.7) |  |
| Current | 175 (11.2) | 336 (12.4) | 377 (10.8) | 134 (19.2) |  |
| Alcohol intake |  |  |  |  |  |  |  |
| None | 1230 (79.1) | 2653 (86.6) | <0.001 | 3161 (83.8) | 722 (86.1) |  | 0.02 |
| Occasional | 152 (12.2) | 195 (7.9) | 303 (9.8) | 44 (6.5) |  |
| Current | 104 (8.7) | 144 (5.5) | 201 (6.4) | 47 (7.3) |  |
| Sleep duration, hours | (n=1482) | (n=2971) |  | (n=3647) | (n=806) |  |  |
| ≤4 hours | 118 (6.4) | 297 (8.1) | <0.0001 | 300 (6.7) | 115 (12.5) |  | <0.0001 |
| 5 hours | 216 (13.5) | 425 (13.4) | 509 (12.9) | 132 (17.0) |  |
| 6 hours | 438 (28.7) | 1041 (36.0) | 1253 (34.6) | 226 (27.1) |  |
| 7-8 hours | 650 (47.5) | 1081 (38.8) | 1454 (42.5) | 277 (36.9) |  |
| ≥9 hours | 60 (3.9) | 127 (3.7) | 131 (3.3) | 56 (6.5) |  |
| Physical activity |  |  |  |  |  |  |  |
| Yes | 976 (64.3) | 1628 (56.5) | <0.0001 | 2169 (59.9) | 435 (53.8) |  | 0.003 |
| No | 510 (35.8) | 1364 (43.5) | 1496 (40.1) | 378 (46.2) |  |
| Social network score | 33.7 ± 12.7 | 27.4 ± 12.7 | <0.0001 | 30.0 ± 13.0 | 26.5 ± 11.3 |  | <0.0001 |
| Loneliness score | 1.2 ± 1.8 | 2.3 ± 2.5 | <0.0001 | 1.8 ± 2.3 | 2.4 ± 2.4 |  | <0.0001 |

ADL, Activity of Daily Living; BMI, Body Mass Index; CES-D, Center for Epidemiologic Studies Depression; HDB, Housing Development Board; IADL, Instrumental Activity of Daily Living; SPMSQ, Short Portable Mental Status Questionnaire

a Unless otherwise stated, due to missing values

b Weighted mean ± SD or weighted column %

**Appendix 4**

**Supplementary Table 3: Association of the ‘binary happiness variable’, ‘happiness score’ and covariates with all-cause mortality, Cox regression analysis**

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Multivariable analysis for the association of the binary happiness variable with all-cause mortality**  HR (95% CI) |  | **Multivariable analysis for the association of ‘happiness score’ with all-cause mortality**  HR (95% CI) |
| **Binary happiness variable** |  |  |  |
| Unhappy | 1.00 |  | - |
| Happy | 0.81 (0.68-0.97)\* |  |  |
| **For each unit increase in ‘happiness score’** | - |  | 0.91 (0.87-0.95)\*\*\* |
|  |  |  |  |
| **Age, years** | 1.07 (1.06-1.08)\*\*\* |  | 1.07 (1.6-1.08)\*\*\* |
| **Sex** |  |  |  |
| Female | 1.00 |  | 1.00 |
| Male | 2.04 (1.61-2.58)\*\*\* |  | 2.09 (1.65-2.64)\*\*\* |
| **Ethnicity** |  |  |  |
| Chinese | 1.00 |  | 1.00 |
| Malay | 1.32 (1.08-1.62)\*\* |  | 1.37 (1.12-1.68)\*\* |
| Indian | 0.99 (0.77-1.27) |  | 1.02 (0.79-1.32) |
| Others | 1.63 (0.82-3.23) |  | 1.66 (0.84-3.28) |
| **Housing** |  |  |  |
| 1-2 room HDB | 1.00 |  | 1.00 |
| 3 room HDB | 0.94 (0.73-1.21) |  | 0.93 (0.72-1.20) |
| 4-5 room HDB/Private | 0.88 (0.69-1.13) |  | 0.87 (0.67-1.12) |
| **Marital status** |  |  |  |
| Married | 1.00 |  | 1.00 |
| Widowed | 1.14 (0.95-1.37) |  | 1.47 (0.78-2.78) |
| Separated | 0.76 (0.28-2.06) |  | 1.00 (0.31-3.22) |
| Divorced | 0.94 (0.52-1.69) |  | 1.21 (0.53-2.79) |
| Never married | 0.78 (0.51-1.17) |  | 0.99 (0.48-2.05) |
| **Living arrangement** |  |  |  |
| Living alone | 1.00 |  | 1.00 |
| With spouse, no children | 1.37(0.68-2.78) |  | 1.38 (0.68-2.081) |
| With children, no spouse | 1.07 (0.7-1.53) |  | 1.09 (0.76-1.57) |
| With spouse and children | 1.42 (0.70-2.87) |  | 1.13 (0.73-1.76) |
| With others only | 1.11 (0.71-1.72) |  | 1.13 (0.73-1.76) |
| **Education** |  |  |  |
| No formal education | 1.00 |  | 1.00 |
| Primary school | 0.95 (0.80-1.13) |  | 0.95 (0.79-1.76) |
| Secondary school | 0.69 (0.54-0.87)\*\* |  | 0.70 (0.55-0.89)\*\* |
| Above secondary school | 0.93 (0.65-1.33) |  | 0.95 (0.66-1.36) |
| **BMI category, kg/m2** |  |  |  |
| <18.5 / Underweight | 1.51 (1.17-1.96)\*\* |  | 1.52 (1.17-1.96)\*\* |
| 18.5-22.9 / Normal weight | 1.00 |  | 1.00 |
| ≥23 / Overweight or Obese | 0.85 (0.72-1.00) |  | 0.85 (0.72-1.96) |
| **Number of chronic diseases** | 1.16 (1.10-1.23)\*\*\* |  | 1.17 (1.10-1.23)\*\*\* |
| **Self-rated health** |  |  |  |
| Very healthy | 0.83 (0.60-1.15) |  | 0.84 (0.61-1.17) |
| Healthier than average | 0.89 (0.73-1.08) |  | 0.87 (0.71-1.05) |
| Of average health | 1.00 |  | 1.00 |
| Somewhat unhealthy | 1.19 (0.97-1.45) |  | 1.17 (0.95-1.43) |
| Very unhealthy | 1.17 (0.72-1.90) |  | 1.12 (0.69-1.82) |
| **CES-D Scale Score (9 negatively worded items)** | 0.97 (0.94-1.00) |  | 0.97 (0.94-1.10) |
| **Number of ADL limitations** | 0.99 (0.90-1.08) |  | 0.99 (0.90-1.08) |
| **Number IADL limitations** | 1.14 (1.07-1.21)\*\*\* |  | 1.14 (1.07-1.21)\*\*\* |
| **Number of mobility limitations** | 1.06(1.01-1.12)\* |  | 1.06 (1.01-1.12)\* |
| **SPMSQ score** | 1.04 (0.99-1.10) |  | 1.04 (0.98-1.10) |
| **Smoking status** |  |  |  |
| None | 1.00 |  | 1.00 |
| Past | 1.49 (1.23-1.82)\*\*\* |  | 1.49 (1.23-1.82)\*\*\* |
| Current | 1.81 (1.45-2.26)\*\*\* |  | 1.79 (1.43-2.23)\*\*\* |
| **Alcohol intake** |  |  |  |
| None | 1.00 |  | 1.00 |
| Occasional | 0.75 (0.55-1.05) |  | 0.75 (0.55-1.03) |
| Current | 1.05 (0.77-1.43) |  | 1.06 (0.78-1.44) |
| **Sleep duration, hours** |  |  |  |
| ≤4 hours | 1.08 (0.86-1.37) |  | 1.08 (0.85-1.37) |
| 5 hours | 1.04 (0.84-1.28) |  | 1.04 (0.84-1.28) |
| 6 hours | 1.00 (0.83-1.19) |  | 0.99 (0.83-1.18) |
| 7-8 hours | 1.00 |  | 1.00 |
| ≥9 hours | 1.41 (1.05-1.89)\* |  | 1.42 (1.06-1.91)\* |
| **Physical activity** |  |  |  |
| Yes | 0.89 (0.76-1.05) |  | 0.90 (0.76-1.05) |
| No | 1.00 |  | 1.00 |
| **Social network score** | 1.00 (0.99-1.00) |  | 1.00 (0.99-1.00) |
| **Loneliness score** | 1.02 (0.99-1.06) |  | 1.02 (0.99-1.05) |

ADL, Activity of Daily Living; BMI, Body Mass Index; CES-D, Center for Epidemiologic Studies Depression; CI: Confidence Interval; HR: Hazard ratios; HDB, Housing Development Board; IADL, Instrumental Activity of Daily Living; SPMSQ, Short Portable Mental Status Questionnaire

\*p<0.05, \*\*p<0.01, \*\*\*p<0.001

**Appendix 5**

**Supplementary Figure 1: Association of ‘happiness score’ with all-cause mortality using restricted cubic spline regression**



**p-value for non-linearity = 0.8688**

Adjusted for demographic (age, sex, ethnicity, marital status, housing type, educational status, and living arrangement), lifestyle (physical activity, smoking status, alcohol intake, and sleep duration), health (body mass index category, self-rated health, number of chronic diseases, number of activity of daily living limitations, number of instrumental activity of daily living limitations, number of mobility limitations, depressive symptoms, and cognitive impairment status), and social (loneliness and social networks) variables

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